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INSTRUMENTS FOR CONTROL AND AUTOMATIC REGULATION

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[A Digest]

The instruments described below were designed for control and automatic regulation of technological processes in the food industry but can also be utilized by other industries. They were developed by the Central Scientific Research Laboratory for Testing and Measuring Instruments and are being serially produced by the Moscow Experimental Factory for Control-Measuring Instruments (Moskip).

POTENTIOMETERS

Type P-4

The P-4 potentiometer is used in laboratory work for determining pH values (0-13) in acid and alkali solutions. With ambient temperature of 15 - 25 degrees and relative humidity of 40 - 60 percent, its error does not exceed ± one millivolt, which corresponds to 0.02 pH.

It is utilized in conjunction with calomel and platinum electrodes and measures the potential difference whose value depends on the concentration of hydrogen ions on the submerged electrodes.

The potentiometer consists of a number of fixed and variable resistors (including a rheostat and a rheochord), dry cell, Weston normal cell, and a zero-galvanometer (one degree $\approx 10^{-6}$ amperes).

During tests, the dry cell is calibrated against the normal cell and then balanced against the emf in the solution. Readings are taken from the scale on

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the rheochord (one division equals one millivolt) which is also shunted by a calibrated resistor. Graphs are provided for converting the readings from millivolts into pH values and for temperature corrections of the test solution.

Type P-5

The P-5 potentiometer (pH meter) is intended for direct use in production. Designed by N. A. Shibko, it is a more elaborate version of Type P-4. Readings in millivolts or in pH units (0-13) are given on the same scale. The over-all error is ± 5 millivolts, which corresponds to 0.1 pH. The basic parts include a normal cell, battery, and galvanometer mounted in a case 263 x 180 x 118 millimeters.

The electric circuit consists of the following four independent sections: (1) for calibration against the normal cell, (2) for measuring pH with a quinhydrone electrode, (3) for measuring pH with an antimony electrode, and (4) for measuring in millivolts.

The use of an antimony electrode for reading pH values directly has the following decisive advantages over other types: (a) it replaces expensive platinum electrodes; (b) the procedure does not require the addition of quinhydrone, hydrogen, or any other substance into the test solution; (c) it can be used for solutions in which a platinum electrode is subject to "poisoning"; and (d) it possesses great durability contrasted with platinum.

Glass electrodes are used in solutions in which platinum (quinhydrone) and antimony electrodes would be "poisoned," and also in cases where exact measurements are required for media with high resistance in current-conducting solutions.

Type LP-3

The LP-3 vacuum-tube potentiometer with glass electrodes operates on 0.00002 milliamperes in the electrode circuit, thereby preventing electrode polarization. Designed by N. A. Shibko, it utilizes a 2-tube DC amplifier, with a directly-heated pentode and triode, for amplifying the current.

The apparatus can be used for measuring pH values in all solutions with glass, antimony, platinum, hydrogen, and quinhydrone electrodes. The same scale gives readings in millivolts and in pH. Temperature correction of the test solution is provided for. Its maximum error from 0-1,300 millivolts, or 0-13 pH, is ± 0.1, while the error for readings from 0-8 pH does not exceed 0.03 pH.

The potentiometer section of the instrument provides for three types of measurements of hydrogen-ion concentration: in plus millivolts, in minus millivolts, and in pH. In all three cases the voltage of a dry cell is calibrated against a normal cell, using a galvanometer to obtain a balance. This voltage is then applied against the voltage across the electrodes and a balance is again achieved by adjusting a rheochord which indicates the desired reading.

Rheostats are used to compensate for temperature of test solution and any asymmetry of the glass electrodes. The amplifier uses 3-volt, 15-volt, and 22-volt batteries. Grid bias adjustment on the pentode grid is used for zeroing the galvanometer.

The instrument is equipped with calomel electrodes paired with platinum and glass electrodes for large and small volumes, and also with combination electrodes containing glass and calomel electrodes for small volumes. The glass electrodes require special care since the glass-wall thickness is 0.03-0.05 millimeters.

"DIEL'KOMETERS"

The diel'kometer instruments manufactured by the Moskip factory operate on the principle of differences in dielectric coefficients of dry substances and water. The moisture content of a substance is determined indirectly by measuring the capacitance of a condenser whose dielectric is the substance itself.

Hygrometer VM-2

This hygrometer is used for determining the moisture content (5-15 percent range) of free-flowing, but not powdery, food products (grain, etc.) which do not contain salts or electrolytes. Its maximum error does not exceed $\pm$ one percent.

The equipment consists essentially of a high-frequency oscillator (110- or 220-volt supply through a stabilizer), and an inductively coupled resonant receiving circuit. The condenser-transmitter consists of two concentrically placed cylinders whose intervening gap is the working space of the condenser.

To determine the moisture content of any substance, it is first necessary to plot a calibration curve from readings for several samples whose moisture content is known beforehand.

Hygrometer VM-3

This instrument, designed by S. A. Tsvetnov, is also used for measuring the moisture content of free-flowing substances in the 5-25 percent moisture range, with an accuracy of $\pm$ 0.5 percent.

It operates on the principle of voltage resonance, using half of the resonance curve. The power supply operates on a 110-220 volt AC source and includes a 6C5 kenotron rectifier and a voltage stabilizer. For battery use, the rectifier unit is cut off. The measuring range is divided into three parts to secure greater accuracy and equal sensitivity for all readings.

The instrument incorporates a beat-frequency self-excited oscillator using a 6C5 tube with plate-grid inductive coupling. This circuit is capacitively coupled to a measuring circuit consisting of an inductance and several condensers connected in parallel (range switching, calibrating, and the condenser-transmitter which is filled with the tested substance).

During operation, the measuring circuit is tuned close to the beat frequency in such a manner that the voltage across the tuned circuit increases along a linear portion of the resonance curve as the capacitance of the condenser-transmitter increases. This voltage is then applied to the grid of a VTVM (vacuum-tube voltmeter) which also uses a 6C5 tube. A feedback circuit is included in the VTVM to minimize the effects of supply voltage fluctuations.

The VTVM tube is normally cut off through cathode bias. With the condenser-transmitter empty, the voltage applied to the VTVM tube is insufficient to overcome this bias. As the transmitter capacitance increases, the voltage developed in the measuring circuit (and applied to the VTVM tube grid) overcomes the bias, causing a plate current to flow. The moisture content of the tested substance can then be obtained from the plate current readings.

Hygrometer VM-1

This instrument is designed for laboratory conditions to determine the moisture content (10-19 percent range) of free-flowing substances by their electrical resistance. It can be used for various substances which have a well-defined relationship between their electrical resistance and moisture content.

The transmitting element of the apparatus consists of two grooved rollers separated by a variable gap (0.5 to 2-3 millimeters), one of which is driven at 30-32 rpm by an electric motor (0.25 kilowatt or larger) and suitable gear box, while the other roller rotates in the opposite direction through cohesive action of the material passing through. If this cohesion is not sufficient at the start, the roller may be rotated by a special knob provided for this purpose, until the apparatus functions properly. Scrapers are also provided on the lower side to keep the rollers clean, and organic glass sections are installed facilitate observations of the test run. The action of the metallic rollers assures uniform results independent of the granular composition of the substance. The gap may be varied by interchanging a plate adjacent to the driven roller. The substance drops into a wooden drawer after passing through the rollers.

The electrical resistance of the substance between the rollers is measured by an ohmmeter with DC supply. The readings may vary over a wide range, 1,500 ohms to 15-16 megohms, corresponding to the moisture content of the tested substance. A multiple-step galvanometer shunt which is used makes it possible to divide the range into a number of sections. The readings are made on a suspended needle galvanometer (0-100 scale) which has a sensitivity of $0.2\text{-}0.4 \times 10^{-6}$ amperes per division. The normal voltage of 85-90 volts for the measuring circuit is supplied by a dry battery.

Fluorometer VF-1

This instrument is used for determining the intensity of fluorescent radiation originating in a liquid medium containing vitamin B_1 or B_2 when it is exposed to light from a quartz lamp. The resulting fluorescence is in functional relationship to the concentration of the fluorescent substance.

The apparatus consists of two selenium photocells, two vessels for the test and standard solutions, quartz light source, light filters, and a measuring circuit with a zero-galvanometer (mirror-type, sensitivity of one degree $\approx$ 0.65×10^{-9} amperes).

The fluorescence generated in the solutions by the light source is transformed into electrical energy in the respective photocells. Adjustments are made with a rheostat and a rheochord until the galvanometer shows a balance. The setting of the rheochord is a measure of the fluorescent intensity and concentration of the analyzed substance in the solution.

The use of a balancing circuit permits operation without regulation of the supply voltage for the quartz lamp since changes in the supply voltage are reflected to an equal extent in both photocells. The high-voltage autotransformer coil has taps for operating the light source on 220, 127, or 110 volts.

The fluorometer can detect concentrations of vitamin B_1 and B_2 as small as 0.03 gamma with an accuracy of 0.04 percent.

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